Inclusive jet production using the k_T algorithm at CDF

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This contribution presents preliminary results on the inclusive jet production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV. The measurements are carried out using the longitudinally invariant k_T algorithm. The inclusive jet cross sections are measured as a function of the jet transverse momentum in five jet rapidity regions for jets in the ranges $54 < p_T^{jet} < 700$ GeV/c and $|y^{jet}| < 2.1$. The results are based on 1.0 fb^{-1} of data collected at CDF during the Run II of the Tevatron. They are in good agreement with next-to-leading order perturbative QCD predictions after including the non-perturbative corrections necessary to account for underlying event and hadronization effects.

The measurement of the inclusive jet production cross section at the Tevatron constitutes an important test of perturbative QCD (pQCD) predictions. As a function of the jet transverse momentum, the cross section extends over more than eight orders of magnitude. The high p_T^{jet} tail probes distances down to about 10^{-19} m and is sensitive to new physics [1]. This measurement can also be used to constrain the Parton Distribution Functions (PDFs) at high x and high Q^2. Run I measurements [2,3] raised a great interest on an apparent excess at high transverse energy. This excess was finally explained within the Standard Model by increasing the gluon PDF at high x as suggested by global PDF analyzes [4]. Recent PDF sets, such as CTEQ6 [5] and MRST2004 [6], include Run I jet data in their global fits.

The preliminary results presented here use a data sample collected at CDF [7] during Run II which corresponds to an integrated luminosity of 1.0 fb^{-1}, over 10 times more than for the Run I measurements. In addition, the jet production rate at high p_T^{jet} has significantly increased thanks to the increase of the Tevatron center of mass energy, from 1.8 TeV in Run I to 1.96 TeV in Run II. It has been multiply by a factor five around 600 GeV/c for instance. Therefore, the p_T^{jet} coverage has been considerably extended, by about 150 GeV/c for central jets.

The measurements are here performed in five different jet rapidity regions up to $|y^{jet}| = 2.1$ [2] using the k_T algorithm [8,9] to reconstruct the jets. The previous study, based on 385 pb^{-1} and limited to jets within $0.1 < |y^{jet}| < 0.7$, was recently published [10]. The extension of the measurement to forward jets is essential to better constrain the PDFs while searching for eventual effects from new physics at higher Q^2 in the central region.

In Run II, new jet algorithms are explored as the cone algorithm used in Run I is not infrared safe and compromises meaningful comparisons with pQCD calculations [11]. Inclusive jet cross section calculations would be affected at next-to-next-to-leading order. As already mentioned, the longitudinally invariant k_T algorithm [8,9] is used in this study. It merges pairs of nearby protojets in order of increasing relative transverse momentum. Inspired by pQCD gluon emissions, it is infrared and collinear safe to all orders in pQCD. Unlike cone based algorithms, it does not include any merging/splitting prescription used to deal with overlapping cones and allows a well defined comparison with the theory without introducing

*R. Lefèvre is supported by the EU funding under the RTN contract: HPRN-CT-2002-00292, Probe for New Physics.

[2] $|y^{jet}| < 0.1$, $0.1 < |y^{jet}| < 0.7$, $0.7 < |y^{jet}| < 1.1$, $1.1 < |y^{jet}| < 1.6$, and $1.6 < |y^{jet}| < 2.1$.

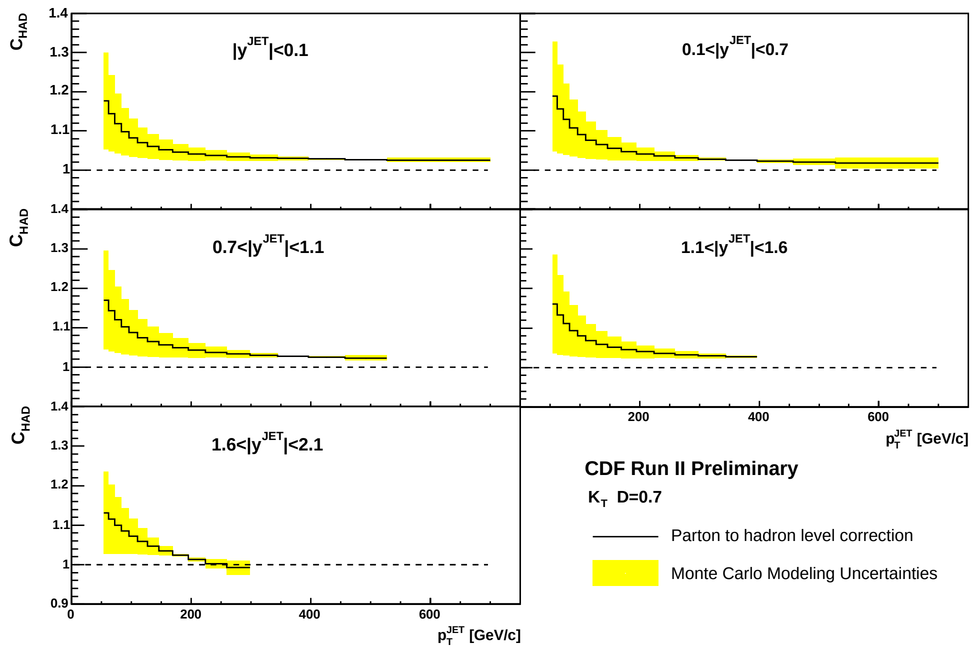

Figure 1. Parton-to-hadron correction factors as a function of p_T^{jet} obtained in the different rapidity regions for jets reconstructed using the k_T algorithm with a D parameter of 0.7.

any arbitrary parameter. On the other hand, it can be more sensitive than cone algorithms to soft contributions such as the underlying event or multiple $p\bar{p}$ interactions per bunch crossing. The k_T algorithm has a parameter D that approximately controls the size of the jets. The measurements are done using a D parameter of 0.7. To make sure that soft contributions are well understood, they are also carried out with $D = 0.5$ and $D = 1.0$ in the rapidity range $0.1 < |y^{jet}| < 0.7$.

Regardless of the jet algorithm used, proper comparisons with the theory require corrections for non-perturbative contributions. Those contributions come from the underlying event and the hadronization processes and become more and more important as p_T^{jet} decreases: they could explain the marginal agreement obtained in the DØ Run I study of the inclusive jet cross section using the k_T algorithm [12]. The corresponding parton-to-hadron correction is derived with PYTHIA 6.203 [13] as the ratio of the predicted inclusive jet cross sections at the hadron level [3] on one hand, and at the parton level [4] turning off the interactions between proton and antiproton remnants, on the other hand. A special set of parameters, tuned on Run I CDF data to reproduce the underlying event activity and denoted as PYTHIA-TUNE A [14], is used. TUNE A has been shown to properly describe the jet shapes measured in Run II [15]. The parton-to-hadron level correction is also evaluated with HERWIG 6.4 [16]. The difference between the two Monte Carlos is considered as the systematic uncertainty on the correction.

Figure 1 shows the parton-to-hadron corrections derived in the different rapidity regions. This correction is only significant at low p_T^{jet}

[3]The hadron level is defined using all final-state particles with lifetime above 10^{-11} s.

[4]The parton level is defined using the partons after final state radiations, *i.e.* just before hadronization.

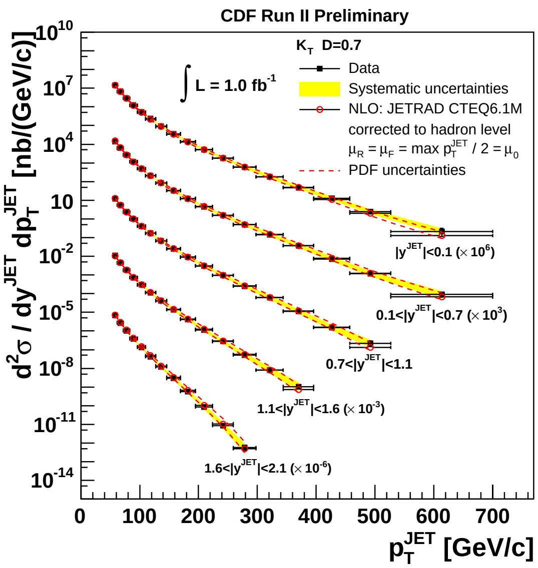

Figure 2. Inclusive jet cross sections as a function of p_T^{jet} measured in five rapidity regions using the k_T algorithm with a D parameter of 0.7 (filled squares) and their comparisons to NLO predictions (open circles).

where it reaches 19% with a relative uncertainty of ±12% for instance in the rapidity region $0.1 < |y^{jet}| < 0.7$.

Figure 2 shows the measured inclusive jet cross sections in the five rapidity regions and their comparisons to next-to-leading order (NLO) pQCD predictions which were calculated with Jetrad [17] using Cteq6.1m PDFs [5] and setting the renormalization and factorization scales to $max(p_T^{jet})/2$. Those predictions are corrected to the hadron level as previously discussed to account for underlying event and hadronization effects.

Figure 3 shows the ratios Data/Theory in the five different rapidity regions. The experimental uncertainties are dominated by the uncertainty on the absolute jet energy scale which is known at a level of ±2% at low p_T^{jet} to ±3% at high p_T^{jet} [18]. An additional ±5.8% normalization uncertainty associated with the luminosity measurement is not included on the plots. The main uncertainty on the pQCD prediction comes from the PDFs, especially from the limited knowledge of the gluon PDF at high x. The theoretical predictions are in good agreement with the measured cross sections over the whole transverse momentum and rapidity range. Specifically, no significant deviation from pQCD is observed at high p_T^{jet}. Figure 3 also shows that Mrst2004 predictions are well within theoretical and experimental uncertainties. The uncertainty on the measured cross section in the most forward region at high p_T^{jet}, compare to that on the theoretical prediction, indicates that the preliminary results reported in this contribution will help to better constrain the gluon PDF at high x.

In the rapidity region $0.1 < |y^{jet}| < 0.7$, similar good agreements between data and theory are observed using a D parameter of 0.5 and of 1.0. This shows that soft contributions are well under control as their importance depends a lot on the size of the jets. At low p_T^{jet}, the non-perturbative correction is for instance 9% for $D = 0.5$ and 37% for $D = 1.0$. Even though the correction itself rapidly increases with D, the corresponding relative uncertainty depends a lot less on the choice of the D parameter: at low p_T^{jet}, it only increases from ±10% for $D = 0.5$ to ±17% for $D = 1.0$.

In conclusion, NLO pQCD predictions are in good agreement with the measured inclusive jet cross sections which extend over more than eight orders of magnitude. The presented study include a careful treatment of non-perturbative effects such as the Underlying Event which are found to be well under control. Those measurements may be used in future PDF global fits to better constrain the gluon PDF at high x, in this respect forward jets appears to be essential.

Acknowledgments

I am very grateful to Stephan Narison for his invitation as well as for his tremendous organization of the QCD 06 International Conference. I would also like to acknowledge the EU for its funding under the RTN contract: HPRN-CT-2002-00292, Probe for New Physics.

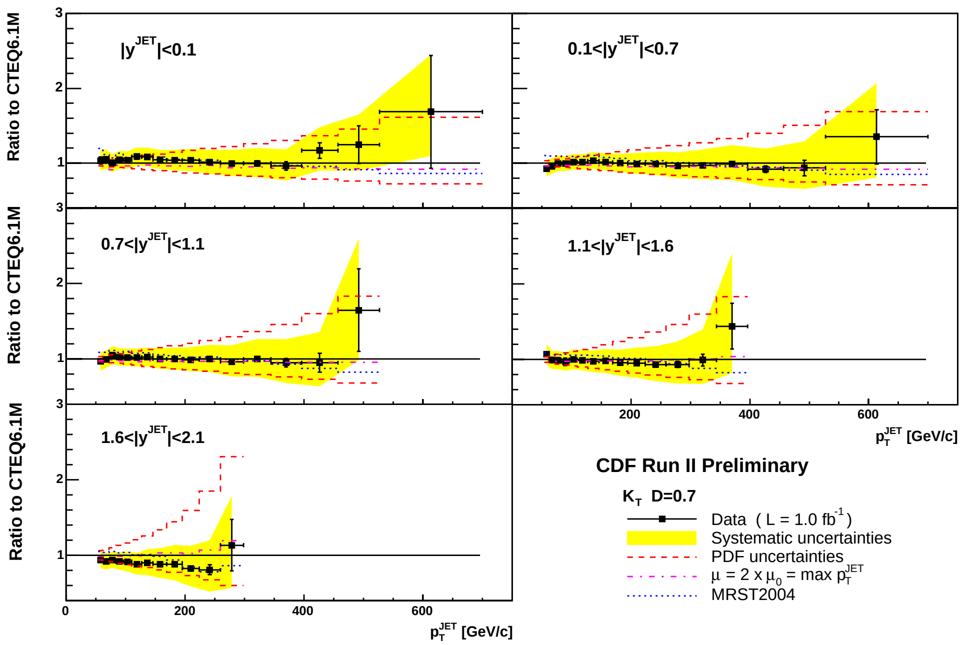

Figure 3. Ratios Data/Theory as a function of p_T^{jet} in the different rapidity regions for jets reconstructed using the k_T algorithm with a D parameter of 0.7.

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